EXHIBIT 1

EXHIBIT A
Supplemental Infringement Contentions for the ’104 Patent

NOTE: The infringement evidence cited below is exemplary and not exhaustive. The cited examples are taken from Android 2.2, 2.3, and Google’s Android websites. Oracle’s infringement contentions apply to all versions of Android having similar or nearly identical code or documentation, including past and expected future releases. Although Oracle’s investigation is ongoing, the ’104 reissue patent is infringed by all versions of Android from Oct. 21, 2008 to the present, including Android 1.1, 1.5 (“Cupcake”), 1.6 (“Donut”), 2.0/2.1 (“Éclair”), 2.2 (“Froyo”), and 2.3 (“Gingerbread”).

The cited source code examples are taken from http://android.git.kernel.org/. The citations are shortened and mirror the file paths shown in http://android.git.kernel.org/. For example, “dalvik\vm\native\InternalNative.c” maps to “[platform/dalvik.git] / vm / native / InternalNative.c” (accessible at http://android.git.kernel.org/?p=platform/dalvik.git;a=blob;f=vm/native/InternalNative.c). Google has apparently made modifications to certain source code files since Oracle’s Preliminary Infringement Contentions were served on December 2, 2010. As such, file paths may refer to earlier versions of Android than what is immediately available at http://android.git.kernel.org/.

It appears that the Android git source code repository (accessible through http://android.git.kernel.org/) was created on or around Oct. 21, 2008. As such, the list of infringing Android versions may be expanded based on what Oracle learns about earlier Android versions.

Oracle has determined that Android devices execute much of the code cited below every time the devices start up. Other cited code is invoked when a developer runs the Android Compatibility Test Suite (CTS), which Google requires manufacturers to execute to certify devices as Android-compatible.[1] The mobile device emulator that Google includes with the Android SDK[2] supports Oracle’s conclusion. The emulator displays log messages to inform developers of what is running on the virtual device. If the developer includes a logging command in part of a program, the emulator will output a log entry every time that part of the program is executed. A developer might use this feature, for example, to test whether an application starts to execute a particular section of code before failing. By adding logging commands to key portions of the Android source code cited below, building an Android system image, and

[1] http://source.android.com/compatibility/android-2.2-cdd.pdf at 10 (“To be considered compatible with Android 2.2, device implementations . . . MUST pass the most recent version of the Android Compatibility Test Suite (CTS) available at the time of the device implementation's software is completed.”).
[2] See http://developer.android.com/guide/developing/devices/emulator.html (“The Android SDK includes a virtual mobile device emulator that runs on your computer. The emulator lets you prototype, develop, and test Android applications without using a physical device. The Android emulator mimics all of the hardware and software features of a typical mobile device, except that it cannot place actual phone calls.”).

loading it into Google's emulator, Oracle determined that many of these code portions are executed even before a user can interact with a device. Thus, Android-compatible devices, when used as Google intends, execute infringing code.

The asserted claims include apparatus, computer system, data processing system, memory, method, computer program product, and computer-readable medium claims. Anyone who makes, uses, offers to sell, sells, or imports a device running Android within or into the United States directly infringes the apparatus and system claims. This includes Google and its downstream licensees, including device manufacturers, carriers, application developers, and end users. Similarly, anyone who engages in the above conduct with respect to storage devices containing Android code directly infringes the computer program product, memory, and computer-readable medium claims. This includes Google and its downstream licensees, including device manufacturers, carriers, application developers, and end users. Anyone who uses a device running Android code directly infringes the method claims. This includes Google and its downstream licensees, including device manufacturers, carriers, application developers, and end users. Google induces and contributes to infringement of all asserted claims by distributing Android code with the intention that it will be executed on mobile devices. The Android code cited below necessarily infringes when it runs because, for example, (1) "when a dex files arrives on a device it will have symbolic references to methods and fields, but afterwards it might just be a simple, a simple integer vtable offset so that when, for invoking a method, instead of having to do say a string-based lookup, it can just simply index into a vtable" (Google I/O 2008 Video, Google I/O 2008 Video, entitled "Dalvik Virtual Machine Internals," presented by Dan Bornstein (Google Android Project), available at http://developer.android.com/videos/index.html#v=ptjedOZEXPM) and (2) "'constant pool' references" are "resolve[d]" "into pointers to VM structs" (*e.g.*, \dalvik\vm\oo\Resolve.h). Moreover, much of the code cited below is executed not only as applications run, but every time a device running Android starts up. Thus Android is not a staple article suitable for substantial non-infringing use. Google supplies its Android code in and from the United States.

The substance of the infringement evidence cited in Claim 11 applies to each asserted claim because the evidence is not limited to a particular form of accused infringement.

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[11-preamble] 11. An apparatus comprising:	The Accused Instrumentalities include devices that run Android or the Android SDK. An Android-based device is an apparatus.
[11-a] a memory containing intermediate form object code constituted by a set of instructions, certain of said instructions	An Android-based device has a memory containing intermediate form object code constituted by a set of instructions. *See, e.g.*, Google I/O 2008 Video, Google I/O 2008 Video, entitled "Dalvik Virtual Machine Internals," presented by Dan Bornstein (Google Android Project), available at http://developer.android.com/videos/index.html#v=ptjedOZEXPM:

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containing one or more symbolic references;	• at 1:22 under “The Big Picture” (“Very briefly, Android is the new platform for mobile devices and it really is the complete stack, includes layers from the OS kernel at the bottom and drivers up through an application framework at the top and it even includes a few applications. You write your applications in the Java programming language and they get translated after compilation into a form that runs on the Dalvik virtual machine.”). • at 2:52 under “What is the Dalvik VM?” (“So the virtual machine, again, is designed based on the constraints of the platform and you can see a few of the key ones. We’re assuming, not a particularly powerful CPU, not very much RAM especially by say today’s desktop standards. An easy way to think about it is as approximately equivalent to like a late 90s desktop machine with a little more modern operating system, but with one very important constraint.”). • at 4:06 under “Problem: Memory Efficiency” (“So, in particular this is, this is kind of how a low end Android device is gonna look in terms of, you know, system characteristics. So, you know, once everything is started up on the system we’re not really expecting there to be that much memory left for applications and, of course, so we try to make the most of that. But one wrinkle in the works is that our, the Android platform security relies on modern process separation. So each application is running in a separate process. There’s a separate address space. It has separate memory and apps are not allowed to interfere with each other at that level and so that means that unless you do something special that 20 megs really isn’t gonna go far at all.”).

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	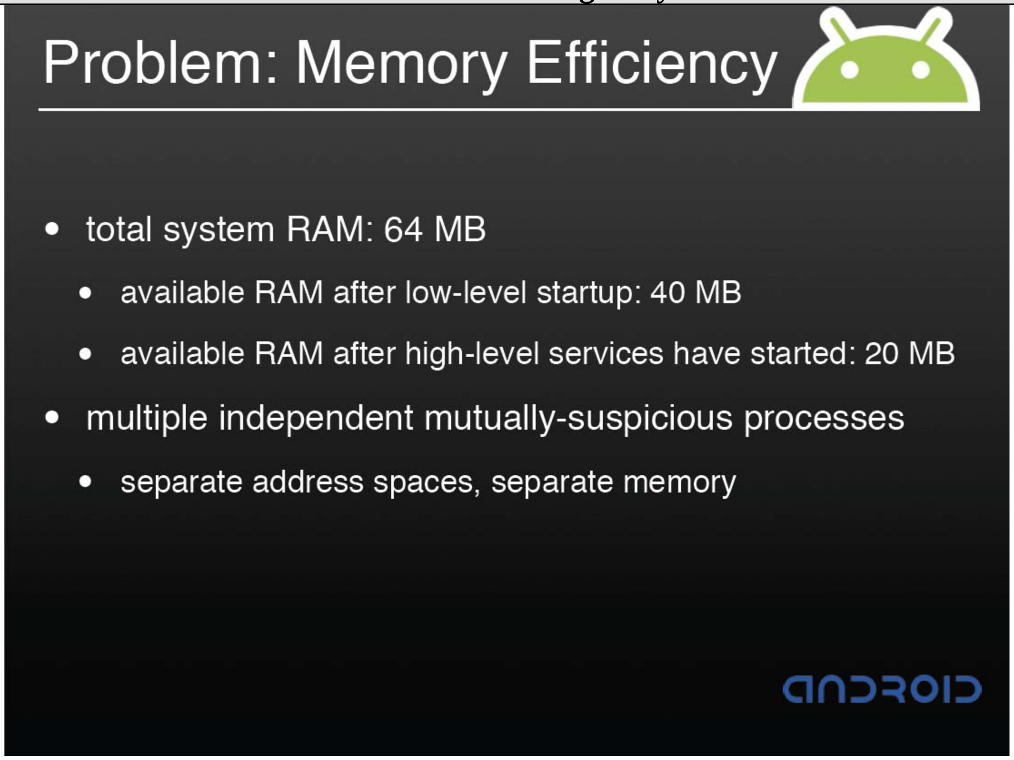 Problem: Memory Efficiency • total system RAM: 64 MB • available RAM after low-level startup: 40 MB • available RAM after high-level services have started: 20 MB • multiple independent mutually-suspicious processes • separate address spaces, separate memory • at 5:05 under “Problem: Memory Efficiency” (“And in addition to this modern platform that, we try to make it, you know, have a rich, have a rich set of APIs for developers to use, we have a fairly large system library. And so again, if you don’t do anything special, well, with a 10 meg library, 20 megs left for apps, that really, really doesn’t leave much space at all. And I think I had a previous slide, we don’t have swap space. So I just wanna emphasize that, so there’s no, if you have 64 megs of RAM, you have 64 megs of RAM and that’s kind of the size of it. Okay.”).

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	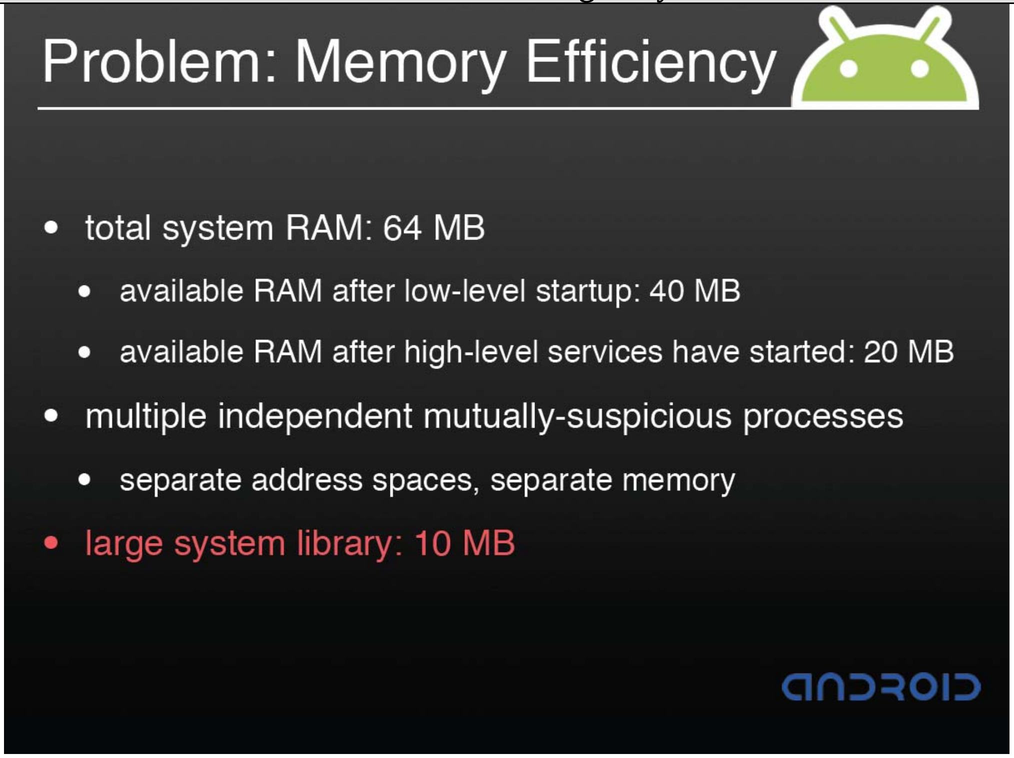 Problem: Memory Efficiency • total system RAM: 64 MB • available RAM after low-level startup: 40 MB • available RAM after high-level services have started: 20 MB • multiple independent mutually-suspicious processes • separate address spaces, separate memory • large system library: 10 MB ANDROID • at 15:38 under “4 Kinds of Memory” (“So our goal, again, is to get as much, as much memory to be mapped clean as possible, but we at least have this out for where we really do have to allocate that we can reduce the cost in terms of the whole system performance.”).

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	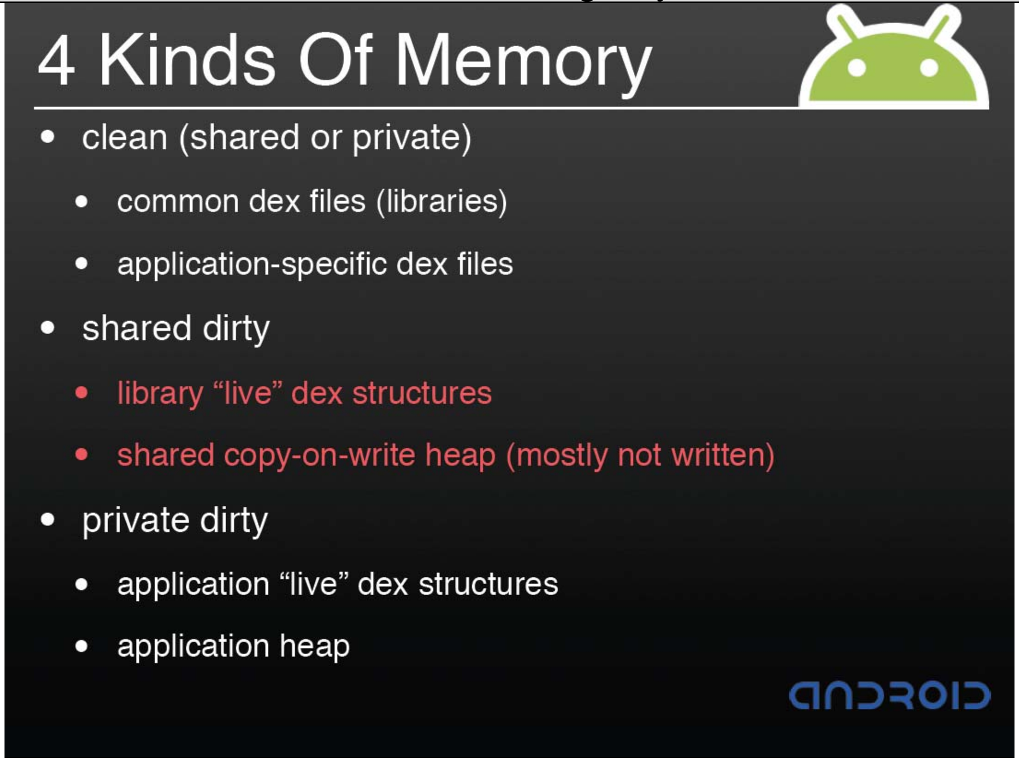 **4 Kinds Of Memory** • clean (shared or private) • common dex files (libraries) • application-specific dex files • shared dirty • library “live” dex structures • shared copy-on-write heap (mostly not written) • private dirty • application “live” dex structures • application heap • at 19:07 under “Problem: CPU Efficiency” (“Again, as I said at the beginning, we’re running on a platform or expecting to run on a platform that looks like what you might have had on your desktop 10 years ago. And, you know, you can see that it’s a fairly slow bus, almost no data cache at all and I just wanna re-emphasize that there’s very little RAM for an app, for applications once you consider all of the things that your device is doing, say, as a phone. It has to answer phone calls, it has to be able to take and send SMSs. All of these things are essential services as far as the user is concerned.”).

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	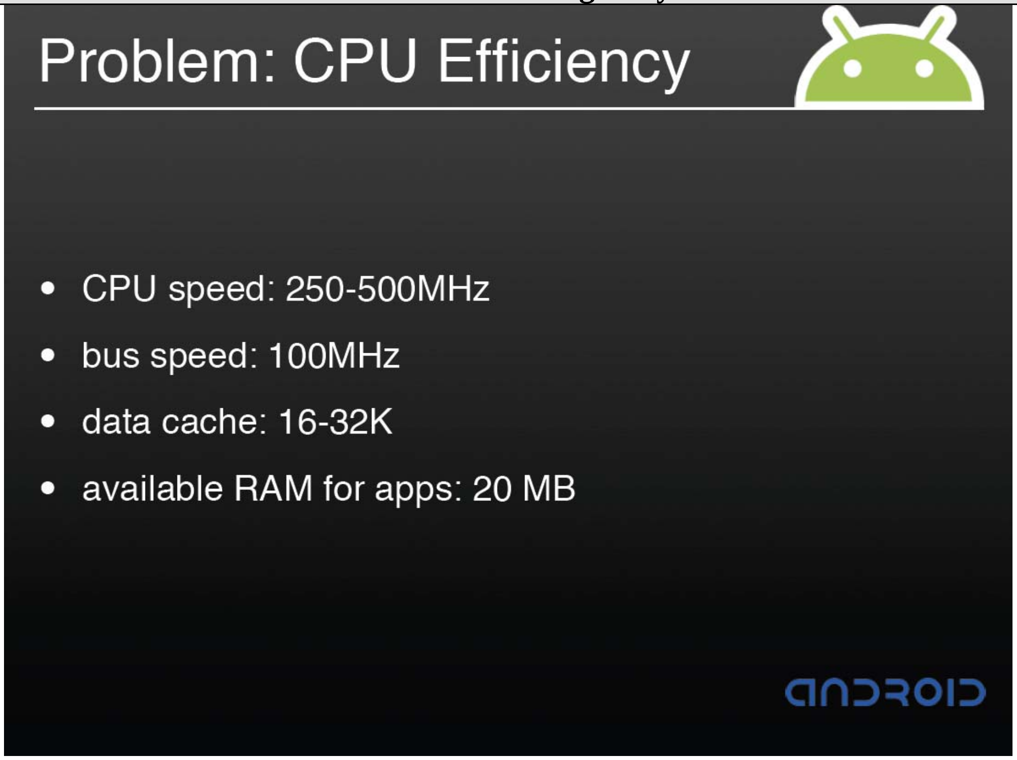 Problem: CPU Efficiency • CPU speed: 250-500MHz • bus speed: 100MHz • data cache: 16-32K • available RAM for apps: 20 MB • at 21:54 under “Install-Time Work” (“So, what are we doing to actually be efficient on the platform? So, first of all, when an application gets installed and also when the system itself gets installed, the platform will, the system will do a lot of work up front to avoid doing work at runtime. So one of the major things we do is verification of dex files and what this means is that as a, as a type safe, reference safe runtime we want to ensure that the code that we’re running doesn’t violate the constraints of the system. It doesn’t violate type safety, it doesn’t, it doesn’t, it doesn’t violate reference safety. And for Android, this is really more about minimizing the app, the impact of bugs in an application as opposed to being a security consideration in and of itself.”).

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	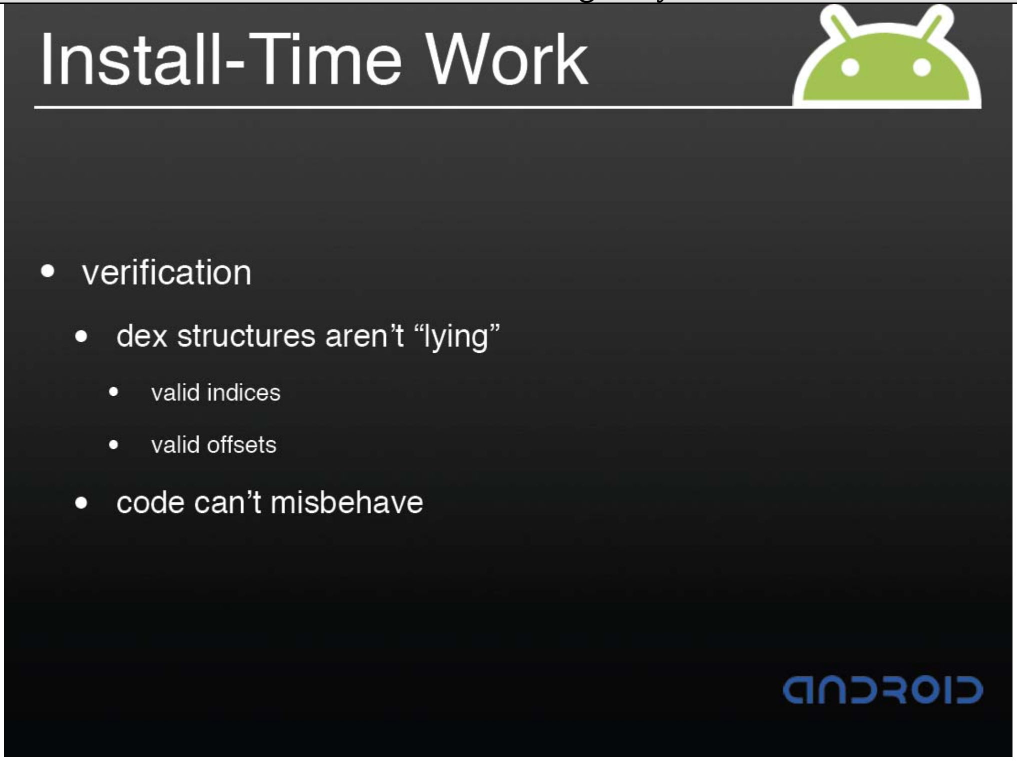 Install-Time Work • verification • dex structures aren't "lying" • valid indices • valid offsets • code can't misbehave • at 23:35 under "Install-Time Work" ("We do optimization. And, so the first time that a dex file lands on a device, we do that verification work, we also, we also augment that file, if we have to we will do byte swapping and pad out structures and in addition, we have a bunch of other things that we do such that when it comes time to run, we can run that much faster. So as an example of static linking, before, when a dex files arrives on a device it will have symbolic references to methods and fields, but afterwards it might just be a simple, a simple integer vtable offset so that when, for invoking a method, instead of having to do say a string-based lookup, it can just simply index into a vtable. And just as another example, you are probably aware that the constructor for java.lang.object has nothing, does nothing inside it and the system can tell. So instead of, instead of actually doing that any time you're constructing an object, we know to avoid just making that call and that actually does make a significant performance impact.").

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	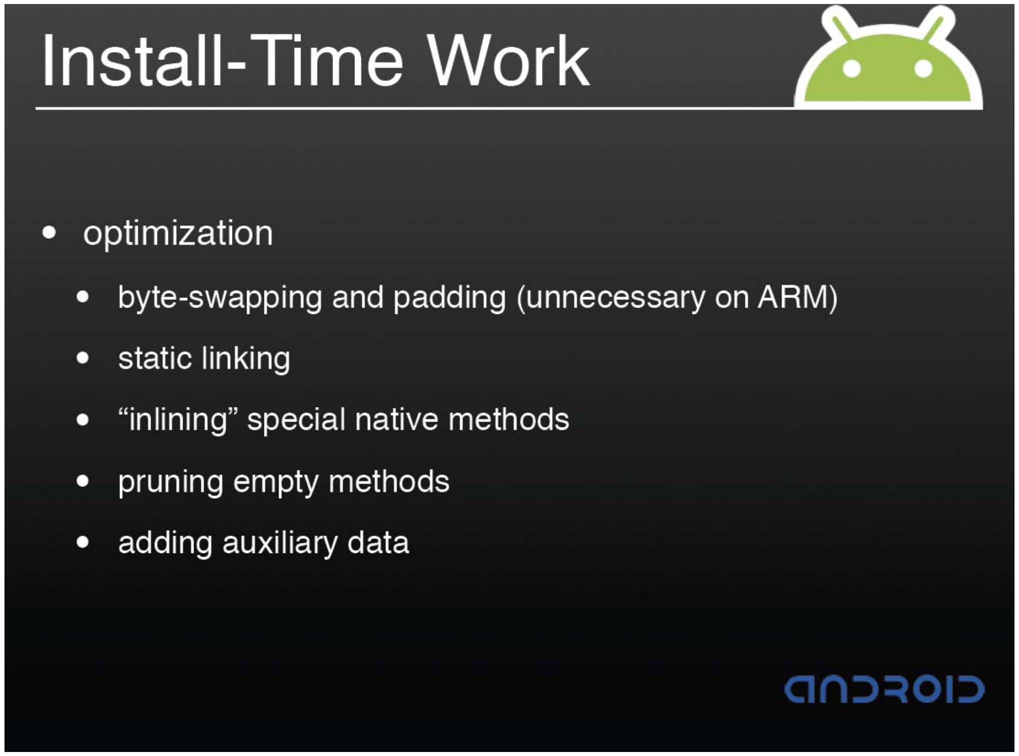 ## Install-Time Work • optimization • byte-swapping and padding (unnecessary on ARM) • static linking • “inlining” special native methods • pruning empty methods • adding auxiliary data Android applications are packaged as .apk files containing intermediate form object code (.dex files). *See, e.g.*, Android Glossary Definition for “.apk file,” available at http://developer.android.com/guide/appendix/glossary.html: .apk file Android application package file. Each Android application is compiled and packaged in a single file that includes all of the application's code (.dex files), resources, assets, and manifest file. The application package file can have any name but must use the .apk extension. For example: myExampleAppname.apk. For convenience, an application package file is often referred to as an ".apk".

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	Android Glossary Definition for “.dex file,” available at http://developer.android.com/guide/appendix/glossary.html: .dex file Compiled Android application code file. Android programs are compiled into .dex (Dalvik Executable) files, which are in turn zipped into a single .apk file on the device. .dex files can be created by automatically translating compiled applications written in the Java programming language. Android Glossary Definition for “Dalvik,” available at http://developer.android.com/guide/appendix/glossary.html: Dalvik The Android platform's virtual machine. The Dalvik VM is an interpreter-only virtual machine that executes files in the Dalvik Executable (.dex) format, a format that is optimized for efficient storage and memory-mappable execution. The virtual machine is register-based, and it can run classes compiled by a Java language compiler that have been transformed into its native format using the included "dx" tool. The VM runs on top of Posix-compliant operating systems, which it relies on for underlying functionality (such as threading and low level memory management). The Dalvik core class library is intended to provide a familiar development base for those used to programming with Java Standard Edition, but it is geared specifically to the needs of a small mobile device. Android Basics, entitled “What is Android?,” available at http://developer.android.com/guide/basics/what-is-android.html: **What is Android?** Android is a software stack for mobile devices that includes an operating system, middleware and key applications. The Android SDK provides the tools and APIs necessary to begin developing applications on the Android platform using the Java programming language.

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	Features • Application framework enabling reuse and replacement of components • Dalvik virtual machine optimized for mobile devices • Integrated browser based on the open source WebKit engine • Optimized graphics powered by a custom 2D graphics library; 3D graphics based on the OpenGL ES 1.0 specification (hardware acceleration optional) • SQLite for structured data storage • Media support for common audio, video, and still image formats (MPEG4, H.264, MP3, AAC, AMR, JPG, PNG, GIF) • GSM Telephony (hardware dependent) • Bluetooth, EDGE, 3G, and WiFi (hardware dependent) • Camera, GPS, compass, and accelerometer (hardware dependent) • Rich development environment including a device emulator, tools for debugging, memory and performance profiling, and a plugin for the Eclipse IDE **Android Architecture** The following diagram shows the major components of the Android operating system. Each section is described in more detail below.

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	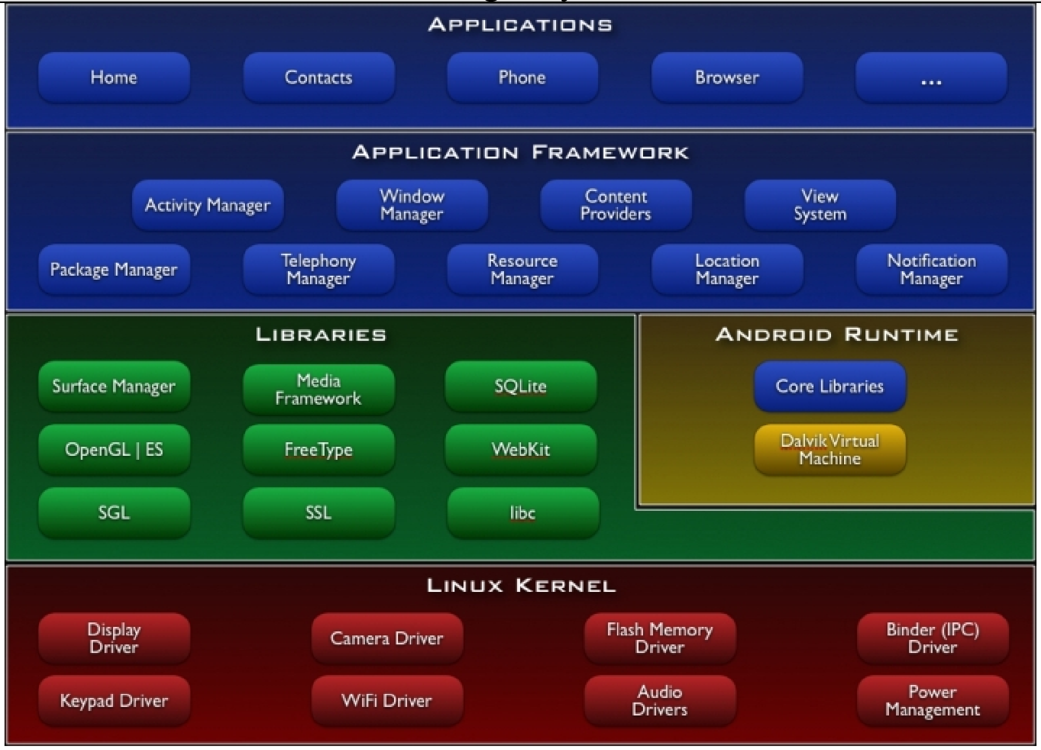 Applications Home Contacts Phone Browser ... Application Framework Activity Manager Window Manager Content Providers View System Package Manager Telephony Manager Resource Manager Location Manager Notification Manager Libraries Surface Manager Media Framework SQLite OpenGL | ES FreeType WebKit SGL SSL libc Android Runtime Core Libraries Dalvik Virtual Machine Linux Kernel Display Driver Camera Driver Flash Memory Driver Binder (IPC) Driver Keypad Driver WiFi Driver Audio Drivers Power Management **Applications** Android will ship with a set of core applications including an email client, SMS program, calendar, maps, browser, contacts, and others. All applications are written using the Java programming language. … **Android Runtime** Android includes a set of core libraries that provides most of the functionality available in the

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	core libraries of the Java programming language. Every Android application runs in its own process, with its own instance of the Dalvik virtual machine. Dalvik has been written so that a device can run multiple VMs efficiently. The Dalvik VM executes files in the Dalvik Executable (.dex) format which is optimized for minimal memory footprint. The VM is register-based, and runs classes compiled by a Java language compiler that have been transformed into the .dex format by the included "dx" tool. The Dalvik VM relies on the Linux kernel for underlying functionality such as threading and low-level memory management. Another way that Android and Android-based devices meet the claim limitation is through the dexopt tool. *See, e.g.*, dalvik\docs\dexopt.html; *see also*, http://android.git.kernel.org/?p=platform/dalvik.git;a=blob;f=docs/dexopt.html: **Dalvik Optimization and Verification With *dexopt*** The Dalvik virtual machine was designed specifically for the Android mobile platform. The target systems have little RAM, store data on slow internal flash memory, and generally have the performance characteristics of decade-old desktop systems. They also run Linux, which provides virtual memory, processes and threads, and UID-based security mechanisms. The features and limitations caused us to focus on certain goals: • Class data, notably bytecode, must be shared between multiple processes to minimize total system memory usage. • The overhead in launching a new app must be minimized to keep the device responsive. • Storing class data in individual files results in a lot of redundancy, especially with respect to strings. To conserve disk space we need to factor this out. • Parsing class data fields adds unnecessary overhead during class loading. Accessing data values (e.g. integers and strings) directly as C types is better.

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	• Bytecode verification is necessary, but slow, so we want to verify as much as possible outside app execution. • Bytecode optimization (quickened instructions, method pruning) is important for speed and battery life. • For security reasons, processes may not edit shared code. The typical VM implementation uncompresses individual classes from a compressed archive and stores them on the heap. This implies a separate copy of each class in every process, and slows application startup because the code must be uncompressed (or at least read off disk in many small pieces). On the other hand, having the bytecode on the local heap makes it easy to rewrite instructions on first use, facilitating a number of different optimizations. The goals led us to make some fundamental decisions: • Multiple classes are aggregated into a single "DEX" file. • DEX files are mapped read-only and shared between processes. • Byte ordering and word alignment are adjusted to suit the local system. • Bytecode verification is mandatory for all classes, but we want to "pre-verify" whatever we can. • Optimizations that require rewriting bytecode must be done ahead of time. • The consequences of these decisions are explained in the following sections. ….
[11-b] and a processor configured to execute said instructions containing one or more symbolic references by determining a numerical reference corresponding to said symbolic reference, storing said	Any device running Android has a processor configured to execute said instructions containing one or more symbolic references by determining a numerical reference corresponding to said symbolic reference, storing said numerical references, and obtaining data in accordance to said numerical references. *See, e.g.*, \dalvik\vm\oo\Resolve.h: /\* * Resolve "constant pool" references into pointers to VM structs. */

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numerical references, and obtaining data in accordance to said numerical references.	#ifndef _DALVIK_OO_RESOLVE #define _DALVIK_OO_RESOLVE /* * "Direct" and "virtual" methods are stored independently. The type of call * used to invoke the method determines which list we search, and whether * we travel up into superclasses. * * (<clinit>, <init>, and methods declared "private" or "static" are stored * in the "direct" list. All others are stored in the "virtual" list.) */ typedef enum MethodType { METHOD_UNKNOWN = 0, METHOD_DIRECT, // <init>, private METHOD_STATIC, // static METHOD_VIRTUAL, // virtual, super METHOD_INTERFACE // interface } MethodType; /* * Resolve a class, given the referring class and a constant pool index * for the DexTypeId. * * Does not initialize the class. * * Throws an exception and returns NULL on failure. */ ClassObject* dvmResolveClass(const ClassObject* referrer, u4 classIdx, bool fromUnverifiedConstant); /* * Resolve a direct, static, or virtual method.

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	```
	 *
	 * Can cause the method's class to be initialized if methodType is
	 * METHOD_STATIC.
	 *
	 * Throws an exception and returns NULL on failure.
	 */
	Method* dvmResolveMethod(const ClassObject* referrer, u4 methodIdx,
	    MethodType methodType);

	/*
	 * Resolve an interface method.
	 *
	 * Throws an exception and returns NULL on failure.
	 */
	Method* dvmResolveInterfaceMethod(const ClassObject* referrer, u4 methodIdx);

	/*
	 * Resolve an instance field.
	 *
	 * Throws an exception and returns NULL on failure.
	 */
	InstField* dvmResolveInstField(const ClassObject* referrer, u4 ifieldIdx);

	/*
	 * Resolve a static field.
	 *
	 * Causes the field's class to be initialized.
	 *
	 * Throws an exception and returns NULL on failure.
	 */
	StaticField* dvmResolveStaticField(const ClassObject* referrer, u4 sfieldIdx);
	```

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	```
	/*
	 * Resolve a "const-string" reference.
	 *
	 * Throws an exception and returns NULL on failure.
	 */
	StringObject* dvmResolveString(const ClassObject* referrer, u4 stringIdx);

	/*
	 * Return debug string constant for enum.
	 */
	const char* dvmMethodTypeStr(MethodType methodType);

	#endif /*_DALVIK_OO_RESOLVE*/
	```
	\dalvik\vm\oo\Resolve.c:
	```
	/*
	 * Resolve classes, methods, fields, and strings.
	 *
	 * According to the VM spec (v2 5.5), classes may be initialized by use
	 * of the "new", "getstatic", "putstatic", or "invokestatic" instructions.
	 * If we are resolving a static method or static field, we make the
	 * initialization check here.
	 *
	 * (NOTE: the verifier has its own resolve functions, which can be invoked
	 * if a class isn't pre-verified.  Those functions must not update the
	 * "resolved stuff" tables for static fields and methods, because they do
	 * not perform initialization.)
	 */
	#include "Dalvik.h"

	#include <stdlib.h>
	```

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	```
	/*
	 * Find the class corresponding to "classIdx", which maps to a class name
	 * string.  It might be in the same DEX file as "referrer", in a different
	 * DEX file, generated by a class loader, or generated by the VM (e.g.
	 * array classes).
	 *
	 * Because the DexTypeId is associated with the referring class' DEX file,
	 * we may have to resolve the same class more than once if it's referred
	 * to from classes in multiple DEX files.  This is a necessary property for
	 * DEX files associated with different class loaders.
	 *
	 * We cache a copy of the lookup in the DexFile's "resolved class" table,
	 * so future references to "classIdx" are faster.
	 *
	 * Note that "referrer" may be in the process of being linked.
	 *
	 * Traditional VMs might do access checks here, but in Dalvik the class
	 * "constant pool" is shared between all classes in the DEX file.  We rely
	 * on the verifier to do the checks for us.
	 *
	 * Does not initialize the class.
	 *
	 * "fromUnverifiedConstant" should only be set if this call is the direct
	 * result of executing a "const-class" or "instance-of" instruction, which
	 * use class constants not resolved by the bytecode verifier.
	 *
	 * Returns NULL with an exception raised on failure.
	 */
	ClassObject* dvmResolveClass(const ClassObject* referrer, u4 classIdx,
	    bool fromUnverifiedConstant)
	```

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	```
	{
	    DvmDex* pDvmDex = referrer->pDvmDex;
	    ClassObject* resClass;
	    const char* className;

	    /*
	     * Check the table first -- this gets called from the other "resolve"
	     * methods.
	     */
	    resClass = dvmDexGetResolvedClass(pDvmDex, classIdx);
	    if (resClass != NULL)
	        return resClass;

	    LOGVV("--- resolving class %u (referrer=%s cl=%p)\n",
	        classIdx, referrer->descriptor, referrer->classLoader);

	    /*
	     * Class hasn't been loaded yet, or is in the process of being loaded
	     * and initialized now.  Try to get a copy.  If we find one, put the
	     * pointer in the DexTypeId.  There isn't a race condition here --
	     * 32-bit writes are guaranteed atomic on all target platforms.  Worst
	     * case we have two threads storing the same value.
	     *
	     * If this is an array class, we'll generate it here.
	     */
	    className = dexStringByTypeIdx(pDvmDex->pDexFile, classIdx);
	    if (className[0] != '\0' && className[1] == '\0') {
	        /* primitive type */
	        resClass = dvmFindPrimitiveClass(className[0]);
	    } else {
	        resClass = dvmFindClassNoInit(className, referrer->classLoader);
	    }
	```

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	See code below

```
if (resClass != NULL) {
    /*
     * If the referrer was pre-verified, the resolved class must come
     * from the same DEX or from a bootstrap class.  The pre-verifier
     * makes assumptions that could be invalidated by a wacky class
     * loader.  (See the notes at the top of oo/Class.c.)
     *
     * The verifier does *not* fail a class for using a const-class
     * or instance-of instruction referring to an unresolveable class,
     * because the result of the instruction is simply a Class object
     * or boolean -- there's no need to resolve the class object during
     * verification.  Instance field and virtual method accesses can
     * break dangerously if we get the wrong class, but const-class and
     * instance-of are only interesting at execution time.  So, if we
     * we got here as part of executing one of the "unverified class"
     * instructions, we skip the additional check.
     *
     * Ditto for class references from annotations and exception
     * handler lists.
     */
    if (!fromUnverifiedConstant &&
        IS_CLASS_FLAG_SET(referrer, CLASS_ISPREVERIFIED))
    {
        ClassObject* resClassCheck = resClass;
        if (dvmIsArrayClass(resClassCheck))
            resClassCheck = resClassCheck->elementClass;

        if (referrer->pDvmDex != resClassCheck->pDvmDex &&
            resClassCheck->classLoader != NULL)
        {
            LOGW("Class resolved by unexpected DEX:"
```

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	```
	" %s(%p):%p ref [%s] %s(%p):%p\n",
	    referrer->descriptor, referrer->classLoader,
	    referrer->pDvmDex,
	    resClass->descriptor, resClassCheck->descriptor,
	    resClassCheck->classLoader, resClassCheck->pDvmDex);
	  LOGW("(%s had used a different %s during pre-verification)\n",
	    referrer->descriptor, resClass->descriptor);
	  dvmThrowException("Ljava/lang/IllegalAccessError;",
	    "Class ref in pre-verified class resolved to unexpected "
	    "implementation");
	  return NULL;
	  }
	}

	LOGVV("##### +ResolveClass(%s): referrer=%s dex=%p ldr=%p ref=%d\n",
	  resClass->descriptor, referrer->descriptor, referrer->pDvmDex,
	  referrer->classLoader, classIdx);

	/*
	 * Add what we found to the list so we can skip the class search
	 * next time through.
	 *
	 * TODO: should we be doing this when fromUnverifiedConstant==true?
	 * (see comments at top of oo/Class.c)
	 */
	dvmDexSetResolvedClass(pDvmDex, classIdx, resClass);
	} else {
	  /* not found, exception should be raised */
	  LOGVV("Class not found: %s\n",
	    dexStringByTypeIdx(pDvmDex->pDexFile, classIdx));
	  assert(dvmCheckException(dvmThreadSelf()));
	}
	```

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	```
	    return resClass;
	}


	/*
	 * Find the method corresponding to "methodRef".
	 *
	 * We use "referrer" to find the DexFile with the constant pool that
	 * "methodRef" is an index into.  We also use its class loader.  The method
	 * being resolved may very well be in a different DEX file.
	 *
	 * If this is a static method, we ensure that the method's class is
	 * initialized.
	 */
	Method* dvmResolveMethod(const ClassObject* referrer, u4 methodIdx,
	    MethodType methodType)
	{
	    DvmDex* pDvmDex = referrer->pDvmDex;
	    ClassObject* resClass;
	    const DexMethodId* pMethodId;
	    Method* resMethod;

	    assert(methodType != METHOD_INTERFACE);

	    LOGVV("--- resolving method %u (referrer=%s)\n", methodIdx,
	        referrer->descriptor);
	    pMethodId = dexGetMethodId(pDvmDex->pDexFile, methodIdx);

	    resClass = dvmResolveClass(referrer, pMethodId->classIdx, false);
	    if (resClass == NULL) {
	        /* can't find the class that the method is a part of */
	```

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	```
	    assert(dvmCheckException(dvmThreadSelf()));
	    return NULL;
	}
	if (dvmIsInterfaceClass(resClass)) {
	    /* method is part of an interface */
	    dvmThrowExceptionWithClassMessage(
	        "Ljava/lang/IncompatibleClassChangeError;",
	        resClass->descriptor);
	    return NULL;
	}

	const char* name = dexStringById(pDvmDex->pDexFile, pMethodId->nameIdx);
	DexProto proto;
	dexProtoSetFromMethodId(&proto, pDvmDex->pDexFile, pMethodId);

	/*
	 * We need to chase up the class hierarchy to find methods defined
	 * in super-classes.  (We only want to check the current class
	 * if we're looking for a constructor; since DIRECT calls are only
	 * for constructors and private methods, we don't want to walk up.)
	 */
	if (methodType == METHOD_DIRECT) {
	    resMethod = dvmFindDirectMethod(resClass, name, &proto);
	} else if (methodType == METHOD_STATIC) {
	    resMethod = dvmFindDirectMethodHier(resClass, name, &proto);
	} else {
	    resMethod = dvmFindVirtualMethodHier(resClass, name, &proto);
	}

	if (resMethod == NULL) {
	    dvmThrowException("Ljava/lang/NoSuchMethodError;", name);
	    return NULL;
	```

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	```
	}

	LOGVV("--- found method %d (%s.%s)\n",
	    methodIdx, resClass->descriptor, resMethod->name);

	/* see if this is a pure-abstract method */
	if (dvmIsAbstractMethod(resMethod) && !dvmIsAbstractClass(resClass)) {
	    dvmThrowException("Ljava/lang/AbstractMethodError;", name);
	    return NULL;
	}

	/*
	 * If we're the first to resolve this class, we need to initialize
	 * it now.  Only necessary for METHOD_STATIC.
	 */
	if (methodType == METHOD_STATIC) {
	    if (!dvmIsClassInitialized(resMethod->clazz) &&
	        !dvmInitClass(resMethod->clazz))
	    {
	        assert(dvmCheckException(dvmThreadSelf()));
	        return NULL;
	    } else {
	        assert(!dvmCheckException(dvmThreadSelf()));
	    }
	} else {
	    /*
	     * Edge case: if the <clinit> for a class creates an instance
	     * of itself, we will call <init> on a class that is still being
	     * initialized by us.
	     */
	    assert(dvmIsClassInitialized(resMethod->clazz) ||
	           dvmIsClassInitializing(resMethod->clazz));
	```

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	(code below)

```
        }

        /*
         * The class is initialized, the method has been found.  Add a pointer
         * to our data structure so we don't have to jump through the hoops again.
         */
        dvmDexSetResolvedMethod(pDvmDex, methodIdx, resMethod);

        return resMethod;
    }

    /*
     * Resolve an interface method reference.
     *
     * Returns NULL with an exception raised on failure.
     */
    Method* dvmResolveInterfaceMethod(const ClassObject* referrer, u4 methodIdx)
    {
        DvmDex* pDvmDex = referrer->pDvmDex;
        ClassObject* resClass;
        const DexMethodId* pMethodId;
        Method* resMethod;
        int i;

        LOGVV("--- resolving interface method %d (referrer=%s)\n",
            methodIdx, referrer->descriptor);
        pMethodId = dexGetMethodId(pDvmDex->pDexFile, methodIdx);

        resClass = dvmResolveClass(referrer, pMethodId->classIdx, false);
        if (resClass == NULL) {
            /* can't find the class that the method is a part of */
            assert(dvmCheckException(dvmThreadSelf()));
```

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	```
	    return NULL;
	}
	if (!dvmIsInterfaceClass(resClass)) {
	    /* whoops */
	    dvmThrowExceptionWithClassMessage(
	        "Ljava/lang/IncompatibleClassChangeError;",
	        resClass->descriptor);
	    return NULL;
	}

	/*
	 * This is the first time the method has been resolved.  Set it in our
	 * resolved-method structure.  It always resolves to the same thing,
	 * so looking it up and storing it doesn't create a race condition.
	 *
	 * If we scan into the interface's superclass -- which is always
	 * java/lang/Object -- we will catch things like:
	 *   interface I ...
	 *   I myobj = (something that implements I)
	 *   myobj.hashCode()
	 * However, the Method->methodIndex will be an offset into clazz->vtable,
	 * rather than an offset into clazz->iftable.  The invoke-interface
	 * code can test to see if the method returned is abstract or concrete,
	 * and use methodIndex accordingly.  I'm not doing this yet because
	 * (a) we waste time in an unusual case, and (b) we're probably going
	 * to fix it in the DEX optimizer.
	 *
	 * We do need to scan the superinterfaces, in case we're invoking a
	 * superinterface method on an interface reference.  The class in the
	 * DexTypeId is for the static type of the object, not the class in
	 * which the method is first defined.  We have the full, flattened
	 * list in "iftable".
	```

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	```
	 */
	const char* methodName =
	    dexStringById(pDvmDex->pDexFile, pMethodId->nameIdx);

	DexProto proto;
	dexProtoSetFromMethodId(&proto, pDvmDex->pDexFile, pMethodId);

	LOGVV("+++ looking for '%s' '%s' in resClass='%s'\n",
	    methodName, methodSig, resClass->descriptor);
	resMethod = dvmFindVirtualMethod(resClass, methodName, &proto);
	if (resMethod == NULL) {
	    LOGVV("+++ did not resolve immediately\n");
	    for (i = 0; i < resClass->iftableCount; i++) {
	        resMethod = dvmFindVirtualMethod(resClass->iftable[i].clazz,
	                        methodName, &proto);
	        if (resMethod != NULL)
	            break;
	    }

	    if (resMethod == NULL) {
	        dvmThrowException("Ljava/lang/NoSuchMethodError;", methodName);
	        return NULL;
	    }
	} else {
	    LOGVV("+++ resolved immediately: %s (%s %d)\n", resMethod->name,
	        resMethod->clazz->descriptor, (u4) resMethod->methodIndex);
	}

	LOGVV("--- found interface method %d (%s.%s)\n",
	    methodIdx, resClass->descriptor, resMethod->name);

	/* we're expecting this to be abstract */
	```

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	```
	    assert(dvmIsAbstractMethod(resMethod));

	    /* interface methods are always public; no need to check access */

	    /*
	     * The interface class *may* be initialized.  According to VM spec
	     * v2 2.17.4, the interfaces a class refers to "need not" be initialized
	     * when the class is initialized.
	     *
	     * It isn't necessary for an interface class to be initialized before
	     * we resolve methods on that interface.
	     *
	     * We choose not to do the initialization now.
	     */
	    //assert(dvmIsClassInitialized(resMethod->clazz));

	    /*
	     * The class is initialized, the method has been found.  Add a pointer
	     * to our data structure so we don't have to jump through the hoops again.
	     */
	    dvmDexSetResolvedMethod(pDvmDex, methodIdx, resMethod);

	    return resMethod;
	}

	/*
	 * Resolve an instance field reference.
	 *
	 * Returns NULL and throws an exception on error (no such field, illegal
	 * access).
	 */
	InstField* dvmResolveInstField(const ClassObject* referrer, u4 ifieldIdx)
	```

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	```
	{
	    DvmDex* pDvmDex = referrer->pDvmDex;
	    ClassObject* resClass;
	    const DexFieldId* pFieldId;
	    InstField* resField;

	    LOGVV("--- resolving field %u (referrer=%s cl=%p)\n",
	        ifieldIdx, referrer->descriptor, referrer->classLoader);

	    pFieldId = dexGetFieldId(pDvmDex->pDexFile, ifieldIdx);

	    /*
	     * Find the field's class.
	     */
	    resClass = dvmResolveClass(referrer, pFieldId->classIdx, false);
	    if (resClass == NULL) {
	        assert(dvmCheckException(dvmThreadSelf()));
	        return NULL;
	    }

	    resField = dvmFindInstanceFieldHier(resClass,
	        dexStringById(pDvmDex->pDexFile, pFieldId->nameIdx),
	        dexStringByTypeIdx(pDvmDex->pDexFile, pFieldId->typeIdx));
	    if (resField == NULL) {
	        dvmThrowException("Ljava/lang/NoSuchFieldError;",
	            dexStringById(pDvmDex->pDexFile, pFieldId->nameIdx));
	        return NULL;
	    }

	    /*
	     * Class must be initialized by now (unless verifier is buggy).  We
	     * could still be in the process of initializing it if the field
	```

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	```
	     * access is from a static initializer.
	     */
	    assert(dvmIsClassInitialized(resField->field.clazz) ||
	           dvmIsClassInitializing(resField->field.clazz));

	    /*
	     * The class is initialized, the method has been found.  Add a pointer
	     * to our data structure so we don't have to jump through the hoops again.
	     */
	    dvmDexSetResolvedField(pDvmDex, ifieldIdx, (Field*)resField);
	    LOGVV("    field %u is %s.%s\n",
	        ifieldIdx, resField->field.clazz->descriptor, resField->field.name);

	    return resField;
	}

	/*
	 * Resolve a static field reference.  The DexFile format doesn't distinguish
	 * between static and instance field references, so the "resolved" pointer
	 * in the Dex struct will have the wrong type.  We trivially cast it here.
	 *
	 * Causes the field's class to be initialized.
	 */
	StaticField* dvmResolveStaticField(const ClassObject* referrer, u4 sfieldIdx)
	{
	    DvmDex* pDvmDex = referrer->pDvmDex;
	    ClassObject* resClass;
	    const DexFieldId* pFieldId;
	    StaticField* resField;

	    pFieldId = dexGetFieldId(pDvmDex->pDexFile, sfieldIdx);
	```

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	```
	/*
	 * Find the field's class.
	 */
	resClass = dvmResolveClass(referrer, pFieldId->classIdx, false);
	if (resClass == NULL) {
	    assert(dvmCheckException(dvmThreadSelf()));
	    return NULL;
	}

	resField = dvmFindStaticFieldHier(resClass,
	            dexStringById(pDvmDex->pDexFile, pFieldId->nameIdx),
	            dexStringByTypeIdx(pDvmDex->pDexFile, pFieldId->typeIdx));
	if (resField == NULL) {
	    dvmThrowException("Ljava/lang/NoSuchFieldError;",
	        dexStringById(pDvmDex->pDexFile, pFieldId->nameIdx));
	    return NULL;
	}

	/*
	 * If we're the first to resolve the field in which this class resides,
	 * we need to do it now.  Note that, if the field was inherited from
	 * a superclass, it is not necessarily the same as "resClass".
	 */
	if (!dvmIsClassInitialized(resField->field.clazz) &&
	    !dvmInitClass(resField->field.clazz))
	{
	    assert(dvmCheckException(dvmThreadSelf()));
	    return NULL;
	}

	/*
	 * The class is initialized, the method has been found.  Add a pointer
	```

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	```
	    * to our data structure so we don't have to jump through the hoops again.
	    */
	   dvmDexSetResolvedField(pDvmDex, sfieldIdx, (Field*) resField);

	   return resField;
	}


	/*
	 * Resolve a string reference.
	 *
	 * Finding the string is easy.  We need to return a reference to a
	 * java/lang/String object, not a bunch of characters, which means the
	 * first time we get here we need to create an interned string.
	 */
	StringObject* dvmResolveString(const ClassObject* referrer, u4 stringIdx)
	{
	   DvmDex* pDvmDex = referrer->pDvmDex;
	   StringObject* strObj;
	   StringObject* internStrObj;
	   const char* utf8;
	   u4 utf16Size;

	   LOGVV("+++ resolving string, referrer is %s\n", referrer->descriptor);

	   /*
	    * Create a UTF-16 version so we can trivially compare it to what's
	    * already interned.
	    */
	   utf8 = dexStringAndSizeById(pDvmDex->pDexFile, stringIdx, &utf16Size);
	   strObj = dvmCreateStringFromCstrAndLength(utf8, utf16Size,
	               ALLOC_DEFAULT);
	```

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	```
	    if (strObj == NULL) {
	        /* ran out of space in GC heap? */
	        assert(dvmCheckException(dvmThreadSelf()));
	        goto bail;
	    }

	    /*
	     * Add it to the intern list.  The return value is the one in the
	     * intern list, which (due to race conditions) may or may not be
	     * the one we just created.  The intern list is synchronized, so
	     * there will be only one "live" version.
	     *
	     * By requesting an immortal interned string, we guarantee that
	     * the returned object will never be collected by the GC.
	     *
	     * A NULL return here indicates some sort of hashing failure.
	     */
	    internStrObj = dvmLookupImmortalInternedString(strObj);
	    dvmReleaseTrackedAlloc((Object*) strObj, NULL);
	    strObj = internStrObj;
	    if (strObj == NULL) {
	        assert(dvmCheckException(dvmThreadSelf()));
	        goto bail;
	    }

	    /* save a reference so we can go straight to the object next time */
	    dvmDexSetResolvedString(pDvmDex, stringIdx, strObj);

	bail:
	    return strObj;
	}
	```

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	```
	/*
	 * For debugging: return a string representing the methodType.
	 */
	const char* dvmMethodTypeStr(MethodType methodType)
	{
	    switch (methodType) {
	    case METHOD_DIRECT:        return "direct";
	    case METHOD_STATIC:        return "static";
	    case METHOD_VIRTUAL:       return "virtual";
	    case METHOD_INTERFACE:     return "interface";
	    case METHOD_UNKNOWN:       return "UNKNOWN";
	    }
	    assert(false);
	    return "BOGUS";
	}
	```
	Another way that Android and Android-based devices meet the claim limitation is through the dexopt tool.
	
	See, *e.g.*, dalvik\docs\dexopt.html; *see also*, http://android.git.kernel.org/?p=platform/dalvik.git;a=blob;f=docs/dexopt.html:
	dexopt
	
	We want to verify and optimize all of the classes in the DEX file. The easiest and safest way to do this is to load all of the classes into the VM and run through them. Anything that fails to load is simply not verified or optimized. Unfortunately, this can cause allocation of some resources that are difficult to release (e.g. loading of native shared libraries), so we don't want to do it in the same virtual machine that we're running applications in.
	
	The solution is to invoke a program called dexopt, which is really just a back door into the VM. It performs an abbreviated VM initialization, loads zero or more DEX files from the bootstrap class path, and then sets about verifying and optimizing whatever it can from the target DEX. On

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	completion, the process exits, freeing all resources. It is possible for multiple VMs to want the same DEX file at the same time. File locking is used to ensure that dexopt is only run once. …. *See also, e.g.*, dalvik\docs\ embedded-vm-control.html#verifier (“The system tries to pre-verify all classes in a DEX file to reduce class load overhead, and performs a series of optimizations to improve runtime performance. Both of these are done by the dexopt command, either in the build system or by the installer. On a development device, dexopt may be run the first time a DEX file is used and whenever it or one of its dependencies is updated ("just-in-time" optimization and verification).”). Dexopt loads the intermediate code class files, and when it encounters a symbolic reference (e.g., virtual method calls, field gets/puts), it determines the numerical reference corresponding to the symbolic reference and stores the numerical reference so that the processor can obtain data in accordance to the numerical references. *See, e.g.*, dalvik\docs\dexopt.html; *see also*, http://android.git.kernel.org/?p=platform/dalvik.git;a=blob;f=docs/dexopt.html: **Dalvik Optimization and Verification With *dexopt*** The Dalvik virtual machine was designed specifically for the Android mobile platform. The target systems have little RAM, store data on slow internal flash memory, and generally have the performance characteristics of decade-old desktop systems. They also run Linux, which provides virtual memory, processes and threads, and UID-based security mechanisms. The features and limitations caused us to focus on certain goals: • Class data, notably bytecode, must be shared between multiple processes to minimize total system memory usage. • The overhead in launching a new app must be minimized to keep the device responsive. • Storing class data in individual files results in a lot of redundancy, especially with respect

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	to strings. To conserve disk space we need to factor this out. • Parsing class data fields adds unnecessary overhead during class loading. Accessing data values (e.g. integers and strings) directly as C types is better. • Bytecode verification is necessary, but slow, so we want to verify as much as possible outside app execution. • Bytecode optimization (quickened instructions, method pruning) is important for speed and battery life. • For security reasons, processes may not edit shared code. The typical VM implementation uncompresses individual classes from a compressed archive and stores them on the heap. This implies a separate copy of each class in every process, and slows application startup because the code must be uncompressed (or at least read off disk in many small pieces). On the other hand, having the bytecode on the local heap makes it easy to rewrite instructions on first use, facilitating a number of different optimizations. The goals led us to make some fundamental decisions: • Multiple classes are aggregated into a single "DEX" file. • DEX files are mapped read-only and shared between processes. • Byte ordering and word alignment are adjusted to suit the local system. • Bytecode verification is mandatory for all classes, but we want to "pre-verify" whatever we can. • Optimizations that require rewriting bytecode must be done ahead of time. • The consequences of these decisions are explained in the following sections. …. **dexopt** We want to verify and optimize all of the classes in the DEX file. The easiest and safest way to do this is to load all of the classes into the VM and run through them. Anything that fails to load is simply not verified or optimized. Unfortunately, this can cause allocation of some resources that are difficult to release (e.g. loading of native shared libraries), so we don't want to do it in the same virtual machine that we're running applications in.

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	The solution is to invoke a program called dexopt, which is really just a back door into the VM. It performs an abbreviated VM initialization, loads zero or more DEX files from the bootstrap class path, and then sets about verifying and optimizing whatever it can from the target DEX. On completion, the process exits, freeing all resources. It is possible for multiple VMs to want the same DEX file at the same time. File locking is used to ensure that dexopt is only run once. …. **Optimization** Virtual machine interpreters typically perform certain optimizations the first time a piece of code is used. Constant pool references are replaced with pointers to internal data structures, operations that always succeed or always work a certain way are replaced with simpler forms. Some of these require information only available at runtime, others can be inferred statically when certain assumptions are made. The Dalvik optimizer does the following: • For virtual method calls, replace the method index with a vtable index. • For instance field get/put, replace the field index with a byte offset. Also, merge the boolean / byte / char / short variants into a single 32-bit form (less code in the interpreter means more room in the CPU I-cache). • Replace a handful of high-volume calls, like String.length(), with "inline" replacements. This skips the usual method call overhead, directly switching from the interpreter to a native implementation. • Prune empty methods. The simplest example is Object.<init>, which does nothing, but must be called whenever any object is allocated. The instruction is replaced with a new version that acts as a no-op unless a debugger is attached. • Append pre-computed data. For example, the VM wants to have a hash table for lookups on class name. Instead of computing this when the DEX file is loaded, we can compute it now, saving heap space and computation time in every VM where the DEX is loaded.

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	All of the instruction modifications involve replacing the opcode with one not defined by the Dalvik specification. This allows us to freely mix optimized and unoptimized instructions. The set of optimized instructions, and their exact representation, is tied closely to the VM version. Most of the optimizations are obvious "wins". The use of raw indices and offsets not only allows us to execute more quickly, we can also skip the initial symbolic resolution. Pre-computation eats up disk space, and so must be done in moderation. There are a couple of potential sources of trouble with these optimizations. First, vtable indices and byte offsets are subject to change if the VM is updated. Second, if a superclass is in a different DEX, and that other DEX is updated, we need to ensure that our optimized indices and offsets are updated as well. A similar but more subtle problem emerges when user-defined class loaders are employed: the class we actually call may not be the one we expected to call. These problems are addressed with dependency lists and some limitations on what can be optimized. *See, e.g.*, dalvik\vm\analysis\ReduceConstants.c: /* Overview When a class, method, field, or string constant is referred to from Dalvik bytecode, the reference takes the form of an integer index value. This value indexes into an array of type_id_item, method_id_item, field_id_item, or string_id_item in the DEX file. The first three themselves contain (directly or indirectly) indexes to strings that the resolver uses to convert the instruction stream index into a pointer to the appropriate object or struct. For example, an invoke-virtual instruction needs to specify which method is to be invoked. The method constant indexes into the method_id_item

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	array, each entry of which has indexes that specify the defining class (type_id_item), method name (string_id_item), and method prototype (proto_id_item). The type_id_item just holds an index to a string_id_item, which holds the file offset to the string with the class name. The VM finds the class by name, then searches through the class' table of virtual methods to find one with a matching name and prototype. This process is fairly expensive, so after the first time it completes successfully, the VM records that the method index resolved to a specific Method struct. On subsequent execution, the VM just pulls the Method ptr out of the resolved-methods array. A similar approach is used with the indexes for classes, fields, and string constants. The problem with this approach is that we need to have a "resolved" entry for every possible class, method, field, and string constant in every DEX file, even if some of those aren't used from code. The DEX string constant table has entries for method prototypes and class names that are never used by the code, and "public static final" fields often turn into immediate constants. The resolution table entries are only 4 bytes each, but there are roughly 200,000 of them in the bootstrap classes alone. DEX optimization removes many index references by replacing virtual method indexes with vtable offsets and instance field indexes with byte offsets. In the earlier example, the method would be resolved at "dexopt" time, and the instruction rewritten as invoke-virtual-quick with the vtable offset. (There are comparatively few classes compared to other constant pool entries, and a much higher percentage (typically 60-70%) are used. The biggest gains come from the string pool.) Using the resolved-entity tables provides a substantial performance improvement, but results in applications allocating 1MB+ of tables that

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	are 70% unused. The used and unused entries are freely intermixed, preventing effective sharing with the zygote process, and resulting in large numbers of private/dirty pages on the native heap as the tables populate on first use. The trick is to reduce the memory usage without decreasing performance. Using smaller resolved-entity tables can actually give us a speed boost, because we'll have a smaller "live" set of pages and make more effective use of the data cache. The approach we're going to use is to determine the set of indexes that could potentially be resolved, generate a mapping from the minimal set to the full set, and append the mapping to the DEX file. This is done at "dexopt" time, because we need to keep the changes in shared/read-only pages or we'll lose the benefits of doing the work. There are two ways to create and use the new mapping: (1) Write the entire full->minimal mapping to the ".odex" file. On every instruction that uses an index, use the mapping to determine the "compressed" constant value, and then use that to index into the resolved-entity tables on the heap. The instruction stream is unchanged, and the resolver can easily tell if a given index is cacheable. (2) Write the inverse miminal->full mapping to the ".odex" file, and rewrite the constants in the instruction stream. The interpreter is unchanged, and the resolver code uses the mapping to find the original data in the DEX. Approach #1 is easier and safer to implement, but it requires a table lookup every time we execute an instruction that includes a constant

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	pool reference. This causes an unacceptable performance hit, chiefly because we're hitting semi-random memory pages and hosing the data cache. This is mitigated somewhat by DEX optimizations that replace the constant with a vtable index or field byte offset. Approach #1 also requires a larger map table, increasing the size of the DEX on disk. One nice property of approach #1 is that most of the DEX file is unmodified, so use of the mapping is a runtime decision. Approach #2 is preferred for performance reasons. The class/method/field/string resolver code has to handle indices from three sources: interpreted instructions, annotations, and exception "catch" lists. Sometimes these occur indirectly, e.g. we need to resolve the declaring class associated with fields and methods when the latter two are themselves resolved. Parsing and rewriting instructions is fairly straightforward, but annotations use a complex format with variable-width index values. We can safely rewrite index values in annotations if we guarantee that the new value is smaller than the original. This implies a two-pass approach: the first determines the set of indexes actually used, the second does the rewrite. Doing the rewrite in a single pass would be much harder. Instances of the "original" indices will still be found in the file; if we try to be all-inclusive we will include some stuff that doesn't need to be there (e.g. we don't generally need to cache the class name string index result, since once we have the class resolved we don't need to look it up by name through the resolver again). There is some potential for performance improvement by caching more than we strictly need, but we can afford to give up a little performance during class loading if it allows us to regain some memory.

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	For safety and debugging, it's useful to distinguish the "compressed" constants in some way, e.g. setting the high bit when we rewrite them. In practice we don't have any free bits: indexes are usually 16-bit values, and we have more than 32,767 string constants in at least one of our core DEX files. Also, this does not work with constants embedded in annotations, because of the variable-width encoding. We should be safe if we can establish a clear distinction between sources of "original" and "compressed" indices. If the values get crossed up we can end up with elusive bugs. The easiest approach is to declare that only indices pulled from certain locations (the instruction stream and/or annotations) are compressed. This prevents us from adding indices in arbitrary locations to the compressed set, but should allow a reasonably robust implementation. … */ dalvik\vm\analysis\DexOptimize.h (similarly in dalvik\vm\analysis\Optimize.h): /* * Abbreviated resolution functions, for use by optimization and verification * code. */ ClassObject* dvmOptResolveClass(ClassObject* referrer, u4 classIdx, VerifyError* pFailure); Method* dvmOptResolveMethod(ClassObject* referrer, u4 methodIdx, MethodType methodType, VerifyError* pFailure); Method* dvmOptResolveInterfaceMethod(ClassObject* referrer, u4 methodIdx); InstField* dvmOptResolveInstField(ClassObject* referrer, u4 ifieldIdx, VerifyError* pFailure); StaticField* dvmOptResolveStaticField(ClassObject* referrer, u4 sfieldIdx,

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	`VerifyError* pFailure);`
	
	dalvik\vm\analysis\DexOptimize.c (similarly in dalvik\vm\analysis\Optimize.c):
	`/*`
	` *`
	`==================================================================`
	`======`
	` *      Optimizations`
	` *`
	`==================================================================`
	`======`
	` */`
	
	`/*`
	` * Perform in-place rewrites on a memory-mapped DEX file.`
	` *`
	` * This happens in a short-lived child process, so we can go nutty with`
	` * loading classes and allocating memory.`
	` */`
	`static bool rewriteDex(u1* addr, int len, bool doVerify, bool doOpt,`
	`    u4* pHeaderFlags, DexClassLookup** ppClassLookup)`
	`{`
	`    u8 prepWhen, loadWhen, verifyWhen, optWhen;`
	`    DvmDex* pDvmDex = NULL;`
	`    bool result = false;`
	
	`    *pHeaderFlags = 0;`
	
	`    LOGV("+++ swapping bytes\n");`
	`    if (dexFixByteOrdering(addr, len) != 0)`
	`        goto bail;`
	`#if __BYTE_ORDER != __LITTLE_ENDIAN`

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	```
	    *pHeaderFlags |= DEX_OPT_FLAG_BIG;
	#endif

	    /*
	     * Now that the DEX file can be read directly, create a DexFile for it.
	     */
	    if (dvmDexFileOpenPartial(addr, len, &pDvmDex) != 0) {
	        LOGE("Unable to create DexFile\n");
	        goto bail;
	    }

	    /*
	     * Create the class lookup table.
	     */
	    //startWhen = dvmGetRelativeTimeUsec();
	    *ppClassLookup = dexCreateClassLookup(pDvmDex->pDexFile);
	    if (*ppClassLookup == NULL)
	        goto bail;

	    /*
	     * Bail out early if they don't want The Works.  The current implementation
	     * doesn't fork a new process if this flag isn't set, so we really don't
	     * want to continue on with the crazy class loading.
	     */
	    if (!doVerify && !doOpt) {
	        result = true;
	        goto bail;
	    }

	    /* this is needed for the next part */
	    pDvmDex->pDexFile->pClassLookup = *ppClassLookup;
	```

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	```
	    prepWhen = dvmGetRelativeTimeUsec();

	    /*
	     * Load all classes found in this DEX file.  If they fail to load for
	     * some reason, they won't get verified (which is as it should be).
	     */
	    if (!loadAllClasses(pDvmDex))
	        goto bail;
	    loadWhen = dvmGetRelativeTimeUsec();

	    /*
	     * Verify all classes in the DEX file.  Export the "is verified" flag
	     * to the DEX file we're creating.
	     */
	    if (doVerify) {
	        dvmVerifyAllClasses(pDvmDex->pDexFile);
	        *pHeaderFlags |= DEX_FLAG_VERIFIED;
	    }
	    verifyWhen = dvmGetRelativeTimeUsec();

	    /*
	     * Optimize the classes we successfully loaded.  If the opt mode is
	     * OPTIMIZE_MODE_VERIFIED, each class must have been successfully
	     * verified or we'll skip it.
	     */
	#ifndef PROFILE_FIELD_ACCESS
	    if (doOpt) {
	        optimizeLoadedClasses(pDvmDex->pDexFile);
	        *pHeaderFlags |= DEX_OPT_FLAG_FIELDS | DEX_OPT_FLAG_INVOCATIONS;
	    }
	#endif
	    optWhen = dvmGetRelativeTimeUsec();
	```

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	```
	    LOGD("DexOpt: load %dms, verify %dms, opt %dms\n",
	        (int) (loadWhen - prepWhen) / 1000,
	        (int) (verifyWhen - loadWhen) / 1000,
	        (int) (optWhen - verifyWhen) / 1000);

	    result = true;

	bail:
	    /* free up storage */
	    dvmDexFileFree(pDvmDex);

	    return result;
	}

	…


	/*
	 * Alternate version of dvmResolveClass for use with verification and
	 * optimization.  Performs access checks on every resolve, and refuses
	 * to acknowledge the existence of classes defined in more than one DEX
	 * file.
	 *
	 * Exceptions caused by failures are cleared before returning.
	 *
	 * On failure, returns NULL, and sets *pFailure if pFailure is not NULL.
	 */
	ClassObject* dvmOptResolveClass(ClassObject* referrer, u4 classIdx,
	    VerifyError* pFailure)
	{
	    DvmDex* pDvmDex = referrer->pDvmDex;
	```

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	```
	ClassObject* resClass;

	/*
	 * Check the table first.  If not there, do the lookup by name.
	 */
	resClass = dvmDexGetResolvedClass(pDvmDex, classIdx);
	if (resClass == NULL) {
	    const char* className = dexStringByTypeIdx(pDvmDex->pDexFile, classIdx);
	    if (className[0] != '\0' && className[1] == '\0') {
	        /* primitive type */
	        resClass = dvmFindPrimitiveClass(className[0]);
	    } else {
	        resClass = dvmFindClassNoInit(className, referrer->classLoader);
	    }
	    if (resClass == NULL) {
	        /* not found, exception should be raised */
	        LOGV("DexOpt: class %d (%s) not found\n",
	            classIdx,
	            dexStringByTypeIdx(pDvmDex->pDexFile, classIdx));
	        if (pFailure != NULL) {
	            /* dig through the wrappers to find the original failure */
	            Object* excep = dvmGetException(dvmThreadSelf());
	            while (true) {
	                Object* cause = dvmGetExceptionCause(excep);
	                if (cause == NULL)
	                    break;
	                excep = cause;
	            }
	            if (strcmp(excep->clazz->descriptor,
	                "Ljava/lang/IncompatibleClassChangeError;") == 0)
	            {
	                *pFailure = VERIFY_ERROR_CLASS_CHANGE;
	```

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	```
	            } else {
	                *pFailure = VERIFY_ERROR_NO_CLASS;
	            }
	        }
	        dvmClearOptException(dvmThreadSelf());
	        return NULL;
	    }

	    /*
	     * Add it to the resolved table so we're faster on the next lookup.
	     */
	    dvmDexSetResolvedClass(pDvmDex, classIdx, resClass);
	}

	/* multiple definitions? */
	if (IS_CLASS_FLAG_SET(resClass, CLASS_MULTIPLE_DEFS)) {
	    LOGI("DexOpt: not resolving ambiguous class '%s'\n",
	        resClass->descriptor);
	    if (pFailure != NULL)
	        *pFailure = VERIFY_ERROR_NO_CLASS;
	    return NULL;
	}

	/* access allowed? */
	tweakLoader(referrer, resClass);
	bool allowed = dvmCheckClassAccess(referrer, resClass);
	untweakLoader(referrer, resClass);
	if (!allowed) {
	    LOGW("DexOpt: resolve class illegal access: %s -> %s\n",
	        referrer->descriptor, resClass->descriptor);
	    if (pFailure != NULL)
	        *pFailure = VERIFY_ERROR_ACCESS_CLASS;
	```

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	```
	            return NULL;
	        }

	        return resClass;
	    }

	    /*
	     * Alternate version of dvmResolveInstField().
	     *
	     * On failure, returns NULL, and sets *pFailure if pFailure is not NULL.
	     */
	    InstField* dvmOptResolveInstField(ClassObject* referrer, u4 ifieldIdx,
	        VerifyError* pFailure)
	    {
	        DvmDex* pDvmDex = referrer->pDvmDex;
	        InstField* resField;

	        resField = (InstField*) dvmDexGetResolvedField(pDvmDex, ifieldIdx);
	        if (resField == NULL) {
	            const DexFieldId* pFieldId;
	            ClassObject* resClass;

	            pFieldId = dexGetFieldId(pDvmDex->pDexFile, ifieldIdx);

	            /*
	             * Find the field's class.
	             */
	            resClass = dvmOptResolveClass(referrer, pFieldId->classIdx, pFailure);
	            if (resClass == NULL) {
	                //dvmClearOptException(dvmThreadSelf());
	                assert(!dvmCheckException(dvmThreadSelf()));
	                if (pFailure != NULL) { assert(!VERIFY_OK(*pFailure)); }
	```

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	`            return NULL;`
	`        }`
	
	`        resField = (InstField*)dvmFindFieldHier(resClass,`
	`            dexStringById(pDvmDex->pDexFile, pFieldId->nameIdx),`
	`            dexStringByTypeIdx(pDvmDex->pDexFile, pFieldId->typeIdx));`
	`        if (resField == NULL) {`
	`            LOGD("DexOpt: couldn't find field %s.%s\n",`
	`                resClass->descriptor,`
	`                dexStringById(pDvmDex->pDexFile, pFieldId->nameIdx));`
	`            if (pFailure != NULL)`
	`                *pFailure = VERIFY_ERROR_NO_FIELD;`
	`            return NULL;`
	`        }`
	`        if (dvmIsStaticField(&resField->field)) {`
	`            LOGD("DexOpt: wanted instance, got static for field %s.%s\n",`
	`                resClass->descriptor,`
	`                dexStringById(pDvmDex->pDexFile, pFieldId->nameIdx));`
	`            if (pFailure != NULL)`
	`                *pFailure = VERIFY_ERROR_CLASS_CHANGE;`
	`            return NULL;`
	`        }`
	
	`        /*`
	`         * Add it to the resolved table so we're faster on the next lookup.`
	`         */`
	`        dvmDexSetResolvedField(pDvmDex, ifieldIdx, (Field*) resField);`
	`    }`
	
	`    /* access allowed? */`
	`    tweakLoader(referrer, resField->field.clazz);`
	`    bool allowed = dvmCheckFieldAccess(referrer, (Field*)resField);`

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	```
	        untweakLoader(referrer, resField->field.clazz);
	        if (!allowed) {
	            LOGI("DexOpt: access denied from %s to field %s.%s\n",
	                referrer->descriptor, resField->field.clazz->descriptor,
	                resField->field.name);
	            if (pFailure != NULL)
	                *pFailure = VERIFY_ERROR_ACCESS_FIELD;
	            return NULL;
	        }

	        return resField;
	    }

	    /*
	     * Alternate version of dvmResolveStaticField().
	     *
	     * Does not force initialization of the resolved field's class.
	     *
	     * On failure, returns NULL, and sets *pFailure if pFailure is not NULL.
	     */
	    StaticField* dvmOptResolveStaticField(ClassObject* referrer, u4 sfieldIdx,
	        VerifyError* pFailure)
	    {
	        DvmDex* pDvmDex = referrer->pDvmDex;
	        StaticField* resField;

	        resField = (StaticField*)dvmDexGetResolvedField(pDvmDex, sfieldIdx);
	        if (resField == NULL) {
	            const DexFieldId* pFieldId;
	            ClassObject* resClass;

	            pFieldId = dexGetFieldId(pDvmDex->pDexFile, sfieldIdx);
	```

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	```
	/*
	 * Find the field's class.
	 */
	resClass = dvmOptResolveClass(referrer, pFieldId->classIdx, pFailure);
	if (resClass == NULL) {
	    //dvmClearOptException(dvmThreadSelf());
	    assert(!dvmCheckException(dvmThreadSelf()));
	    if (pFailure != NULL) { assert(!VERIFY_OK(*pFailure)); }
	    return NULL;
	}

	resField = (StaticField*)dvmFindFieldHier(resClass,
	            dexStringById(pDvmDex->pDexFile, pFieldId->nameIdx),
	            dexStringByTypeIdx(pDvmDex->pDexFile, pFieldId->typeIdx));
	if (resField == NULL) {
	    LOGD("DexOpt: couldn't find static field\n");
	    if (pFailure != NULL)
	        *pFailure = VERIFY_ERROR_NO_FIELD;
	    return NULL;
	}
	if (!dvmIsStaticField(&resField->field)) {
	    LOGD("DexOpt: wanted static, got instance for field %s.%s\n",
	        resClass->descriptor,
	        dexStringById(pDvmDex->pDexFile, pFieldId->nameIdx));
	    if (pFailure != NULL)
	        *pFailure = VERIFY_ERROR_CLASS_CHANGE;
	    return NULL;
	}

	/*
	 * Add it to the resolved table so we're faster on the next lookup.
	```

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	```
	         *
	         * We can only do this if we're in "dexopt", because the presence
	         * of a valid value in the resolution table implies that the class
	         * containing the static field has been initialized.
	         */
	        if (gDvm.optimizing)
	            dvmDexSetResolvedField(pDvmDex, sfieldIdx, (Field*) resField);
	    }

	    /* access allowed? */
	    tweakLoader(referrer, resField->field.clazz);
	    bool allowed = dvmCheckFieldAccess(referrer, (Field*)resField);
	    untweakLoader(referrer, resField->field.clazz);
	    if (!allowed) {
	        LOGI("DexOpt: access denied from %s to field %s.%s\n",
	            referrer->descriptor, resField->field.clazz->descriptor,
	            resField->field.name);
	        if (pFailure != NULL)
	            *pFailure = VERIFY_ERROR_ACCESS_FIELD;
	        return NULL;
	    }

	    return resField;
	}

	/*
	 * Rewrite an iget/iput instruction.  These all have the form:
	 *   op vA, vB, field@CCCC
	 *
	 * Where vA holds the value, vB holds the object reference, and CCCC is
	 * the field reference constant pool offset.  We want to replace CCCC
	 * with the byte offset from the start of the object.
	```

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	```
	 *
	 * "clazz" is the referring class.  We need this because we verify
	 * access rights here.
	 */
	static void rewriteInstField(Method* method, u2* insns, OpCode newOpc)
	{
	    ClassObject* clazz = method->clazz;
	    u2 fieldIdx = insns[1];
	    InstField* field;
	    int byteOffset;

	    field = dvmOptResolveInstField(clazz, fieldIdx, NULL);
	    if (field == NULL) {
	        LOGI("DexOpt: unable to optimize field ref 0x%04x at 0x%02x in %s.%s\n",
	            fieldIdx, (int) (insns - method->insns), clazz->descriptor,
	            method->name);
	        return;
	    }

	    if (field->byteOffset >= 65536) {
	        LOGI("DexOpt: field offset exceeds 64K (%d)\n", field->byteOffset);
	        return;
	    }

	    insns[0] = (insns[0] & 0xff00) | (u2) newOpc;
	    insns[1] = (u2) field->byteOffset;
	    LOGVV("DexOpt: rewrote access to %s.%s --> %d\n",
	        field->field.clazz->descriptor, field->field.name,
	        field->byteOffset);
	}

	/*
	```

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	```
	 * Alternate version of dvmResolveMethod().
	 *
	 * Doesn't throw exceptions, and checks access on every lookup.
	 *
	 * On failure, returns NULL, and sets *pFailure if pFailure is not NULL.
	 */
	Method* dvmOptResolveMethod(ClassObject* referrer, u4 methodIdx,
	    MethodType methodType, VerifyError* pFailure)
	{
	    DvmDex* pDvmDex = referrer->pDvmDex;
	    Method* resMethod;

	    assert(methodType == METHOD_DIRECT ||
	           methodType == METHOD_VIRTUAL ||
	           methodType == METHOD_STATIC);

	    LOGVV("--- resolving method %u (referrer=%s)\n", methodIdx,
	        referrer->descriptor);

	    resMethod = dvmDexGetResolvedMethod(pDvmDex, methodIdx);
	    if (resMethod == NULL) {
	        const DexMethodId* pMethodId;
	        ClassObject* resClass;

	        pMethodId = dexGetMethodId(pDvmDex->pDexFile, methodIdx);

	        resClass = dvmOptResolveClass(referrer, pMethodId->classIdx, pFailure);
	        if (resClass == NULL) {
	            /*
	             * Can't find the class that the method is a part of, or don't
	             * have permission to access the class.
	             */
	```

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	```
	    LOGV("DexOpt: can't find called method's class (?.%s)\n",
	        dexStringById(pDvmDex->pDexFile, pMethodId->nameIdx));
	    if (pFailure != NULL) { assert(!VERIFY_OK(*pFailure)); }
	    return NULL;
	}
	if (dvmIsInterfaceClass(resClass)) {
	    /* method is part of an interface; this is wrong method for that */
	    LOGW("DexOpt: method is in an interface\n");
	    if (pFailure != NULL)
	        *pFailure = VERIFY_ERROR_GENERIC;
	    return NULL;
	}

	/*
	 * We need to chase up the class hierarchy to find methods defined
	 * in super-classes.  (We only want to check the current class
	 * if we're looking for a constructor.)
	 */
	DexProto proto;
	dexProtoSetFromMethodId(&proto, pDvmDex->pDexFile, pMethodId);

	if (methodType == METHOD_DIRECT) {
	    resMethod = dvmFindDirectMethod(resClass,
	        dexStringById(pDvmDex->pDexFile, pMethodId->nameIdx), &proto);
	} else {
	    /* METHOD_STATIC or METHOD_VIRTUAL */
	    resMethod = dvmFindMethodHier(resClass,
	        dexStringById(pDvmDex->pDexFile, pMethodId->nameIdx), &proto);
	}

	if (resMethod == NULL) {
	    LOGV("DexOpt: couldn't find method '%s'\n",
	```

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	`        dexStringById(pDvmDex->pDexFile, pMethodId->nameIdx));`
	`    if (pFailure != NULL)`
	`        *pFailure = VERIFY_ERROR_NO_METHOD;`
	`    return NULL;`
	`}`
	`if (methodType == METHOD_STATIC) {`
	`    if (!dvmIsStaticMethod(resMethod)) {`
	`        LOGD("DexOpt: wanted static, got instance for method %s.%s\n",`
	`            resClass->descriptor, resMethod->name);`
	`        if (pFailure != NULL)`
	`            *pFailure = VERIFY_ERROR_CLASS_CHANGE;`
	`        return NULL;`
	`    }`
	`} else if (methodType == METHOD_VIRTUAL) {`
	`    if (dvmIsStaticMethod(resMethod)) {`
	`        LOGD("DexOpt: wanted instance, got static for method %s.%s\n",`
	`            resClass->descriptor, resMethod->name);`
	`        if (pFailure != NULL)`
	`            *pFailure = VERIFY_ERROR_CLASS_CHANGE;`
	`        return NULL;`
	`    }`
	`}`
	
	`/* see if this is a pure-abstract method */`
	`if (dvmIsAbstractMethod(resMethod) && !dvmIsAbstractClass(resClass)) {`
	`    LOGW("DexOpt: pure-abstract method '%s' in %s\n",`
	`        dexStringById(pDvmDex->pDexFile, pMethodId->nameIdx),`
	`        resClass->descriptor);`
	`    if (pFailure != NULL)`
	`        *pFailure = VERIFY_ERROR_GENERIC;`
	`    return NULL;`
	`}`

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	```
	        /*
	         * Add it to the resolved table so we're faster on the next lookup.
	         *
	         * We can only do this for static methods if we're not in "dexopt",
	         * because the presence of a valid value in the resolution table
	         * implies that the class containing the static field has been
	         * initialized.
	         */
	        if (methodType != METHOD_STATIC || gDvm.optimizing)
	            dvmDexSetResolvedMethod(pDvmDex, methodIdx, resMethod);
	    }

	    LOGVV("--- found method %d (%s.%s)\n",
	        methodIdx, resMethod->clazz->descriptor, resMethod->name);

	    /* access allowed? */
	    tweakLoader(referrer, resMethod->clazz);
	    bool allowed = dvmCheckMethodAccess(referrer, resMethod);
	    untweakLoader(referrer, resMethod->clazz);
	    if (!allowed) {
	        IF_LOGI() {
	            char* desc = dexProtoCopyMethodDescriptor(&resMethod->prototype);
	            LOGI("DexOpt: illegal method access (call %s.%s %s from %s)\n",
	                resMethod->clazz->descriptor, resMethod->name, desc,
	                referrer->descriptor);
	            free(desc);
	        }
	        if (pFailure != NULL)
	            *pFailure = VERIFY_ERROR_ACCESS_METHOD;
	        return NULL;
	    }
	```

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	```
	    return resMethod;
	}

	/*
	 * Rewrite invoke-virtual, invoke-virtual/range, invoke-super, and
	 * invoke-super/range.  These all have the form:
	 *   op vAA, meth@BBBB, reg stuff @CCCC
	 *
	 * We want to replace the method constant pool index BBBB with the
	 * vtable index.
	 */
	static bool rewriteVirtualInvoke(Method* method, u2* insns, OpCode newOpc)
	{
	    ClassObject* clazz = method->clazz;
	    Method* baseMethod;
	    u2 methodIdx = insns[1];

	    baseMethod = dvmOptResolveMethod(clazz, methodIdx, METHOD_VIRTUAL, NULL);
	    if (baseMethod == NULL) {
	        LOGD("DexOpt: unable to optimize virt call 0x%04x at 0x%02x in %s.%s\n",
	            methodIdx,
	            (int) (insns - method->insns), clazz->descriptor,
	            method->name);
	        return false;
	    }

	    assert((insns[0] & 0xff) == OP_INVOKE_VIRTUAL ||
	            (insns[0] & 0xff) == OP_INVOKE_VIRTUAL_RANGE ||
	            (insns[0] & 0xff) == OP_INVOKE_SUPER ||
	            (insns[0] & 0xff) == OP_INVOKE_SUPER_RANGE);
	```

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	```
	    /*
	     * Note: Method->methodIndex is a u2 and is range checked during the
	     * initial load.
	     */
	    insns[0] = (insns[0] & 0xff00) \| (u2) newOpc;
	    insns[1] = baseMethod->methodIndex;

	    //LOGI("DexOpt: rewrote call to %s.%s --> %s.%s\n",
	    //    method->clazz->descriptor, method->name,
	    //    baseMethod->clazz->descriptor, baseMethod->name);

	    return true;
	}

	…
	/*
	 * Resolve an interface method reference.
	 *
	 * No method access check here -- interface methods are always public.
	 *
	 * Returns NULL if the method was not found.  Does not throw an exception.
	 */
	Method* dvmOptResolveInterfaceMethod(ClassObject* referrer, u4 methodIdx)
	{
	    DvmDex* pDvmDex = referrer->pDvmDex;
	    Method* resMethod;
	    int i;

	    LOGVV("--- resolving interface method %d (referrer=%s)\n",
	        methodIdx, referrer->descriptor);

	    resMethod = dvmDexGetResolvedMethod(pDvmDex, methodIdx);
	```

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	```
	    if (resMethod == NULL) {
	        const DexMethodId* pMethodId;
	        ClassObject* resClass;

	        pMethodId = dexGetMethodId(pDvmDex->pDexFile, methodIdx);

	        resClass = dvmOptResolveClass(referrer, pMethodId->classIdx, NULL);
	        if (resClass == NULL) {
	            /* can't find the class that the method is a part of */
	            dvmClearOptException(dvmThreadSelf());
	            return NULL;
	        }
	        if (!dvmIsInterfaceClass(resClass)) {
	            /* whoops */
	            LOGI("Interface method not part of interface class\n");
	            return NULL;
	        }

	        const char* methodName =
	            dexStringById(pDvmDex->pDexFile, pMethodId->nameIdx);
	        DexProto proto;
	        dexProtoSetFromMethodId(&proto, pDvmDex->pDexFile, pMethodId);

	        LOGVV("+++ looking for '%s' '%s' in resClass='%s'\n",
	            methodName, methodSig, resClass->descriptor);
	        resMethod = dvmFindVirtualMethod(resClass, methodName, &proto);
	        if (resMethod == NULL) {
	            /* scan superinterfaces and superclass interfaces */
	            LOGVV("+++ did not resolve immediately\n");
	            for (i = 0; i < resClass->iftableCount; i++) {
	                resMethod = dvmFindVirtualMethod(resClass->iftable[i].clazz,
	                                methodName, &proto);
	```

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	```
	            if (resMethod != NULL)
	                break;
	        }

	        if (resMethod == NULL) {
	            LOGVV("+++ unable to resolve method %s\n", methodName);
	            return NULL;
	        }
	    } else {
	        LOGVV("+++ resolved immediately: %s (%s %d)\n", resMethod->name,
	            resMethod->clazz->descriptor, (u4) resMethod->methodIndex);
	    }

	    /* we're expecting this to be abstract */
	    if (!dvmIsAbstractMethod(resMethod)) {
	        char* desc = dexProtoCopyMethodDescriptor(&resMethod->prototype);
	        LOGW("Found non-abstract interface method %s.%s %s\n",
	            resMethod->clazz->descriptor, resMethod->name, desc);
	        free(desc);
	        return NULL;
	    }

	    /*
	     * Add it to the resolved table so we're faster on the next lookup.
	     */
	    dvmDexSetResolvedMethod(pDvmDex, methodIdx, resMethod);
	}

	LOGVV("--- found interface method %d (%s.%s)\n",
	    methodIdx, resMethod->clazz->descriptor, resMethod->name);

	/* interface methods are always public; no need to check access */
	```

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	```
	        return resMethod;
	    }

	    …
	```
	 See also, *e.g.*, dalvik\vm\analysis\DexOptimize.c (similarly in dalvik\vm\analysis\Optimize.c)::
	```
	    /*
	     * Optimize instructions in a method.
	     *
	     * Returns "true" if all went well, "false" if we bailed out early when
	     * something failed.
	     */
	    static bool optimizeMethod(Method* method, const InlineSub* inlineSubs)
	    {
	        u4 insnsSize;
	        u2* insns;
	        u2 inst;

	        if (dvmIsNativeMethod(method) || dvmIsAbstractMethod(method))
	            return true;

	        insns = (u2*) method->insns;
	        assert(insns != NULL);
	        insnsSize = dvmGetMethodInsnsSize(method);

	        while (insnsSize > 0) {
	            int width;

	            inst = *insns & 0xff;

	            switch (inst) {
	```

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	```
	case OP_IGET:
	case OP_IGET_BOOLEAN:
	case OP_IGET_BYTE:
	case OP_IGET_CHAR:
	case OP_IGET_SHORT:
	    rewriteInstField(method, insns, OP_IGET_s);
	    break;
	case OP_IGET_WIDE:
	    rewriteInstField(method, insns, OP_IGET_WIDE_QUICK);
	    break;
	case OP_IGET_OBJECT:
	    rewriteInstField(method, insns, OP_IGET_OBJECT_QUICK);
	    break;
	case OP_IPUT:
	case OP_IPUT_BOOLEAN:
	case OP_IPUT_BYTE:
	case OP_IPUT_CHAR:
	case OP_IPUT_SHORT:
	    rewriteInstField(method, insns, OP_IPUT_QUICK);
	    break;
	case OP_IPUT_WIDE:
	    rewriteInstField(method, insns, OP_IPUT_WIDE_QUICK);
	    break;
	case OP_IPUT_OBJECT:
	    rewriteInstField(method, insns, OP_IPUT_OBJECT_QUICK);
	    break;

	case OP_INVOKE_VIRTUAL:
	    if (!rewriteExecuteInline(method, insns, METHOD_VIRTUAL,inlineSubs))
	    {
	        if (!rewriteVirtualInvoke(method, insns, OP_INVOKE_VIRTUAL_QUICK))
	            return false;
	```

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	```
	    }
	    break;
	case OP_INVOKE_VIRTUAL_RANGE:
	    if (!rewriteExecuteInlineRange(method, insns, METHOD_VIRTUAL,
	            inlineSubs))
	    {
	        if (!rewriteVirtualInvoke(method, insns,
	                OP_INVOKE_VIRTUAL_QUICK_RANGE))
	        {
	            return false;
	        }
	    }
	    break;
	case OP_INVOKE_SUPER:
	    if (!rewriteVirtualInvoke(method, insns, OP_INVOKE_SUPER_QUICK))
	        return false;
	    break;
	case OP_INVOKE_SUPER_RANGE:
	    if (!rewriteVirtualInvoke(method, insns, OP_INVOKE_SUPER_QUICK_RANGE))
	        return false;
	    break;

	case OP_INVOKE_DIRECT:
	    if (!rewriteExecuteInline(method, insns, METHOD_DIRECT, inlineSubs))
	    {
	        if (!rewriteEmptyDirectInvoke(method, insns))
	            return false;
	    }
	    break;
	case OP_INVOKE_DIRECT_RANGE:
	    rewriteExecuteInlineRange(method, insns, METHOD_DIRECT, inlineSubs);
	    break;
	```

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	```
	        case OP_INVOKE_STATIC:
	            rewriteExecuteInline(method, insns, METHOD_STATIC, inlineSubs);
	            break;
	        case OP_INVOKE_STATIC_RANGE:
	            rewriteExecuteInlineRange(method, insns, METHOD_STATIC, inlineSubs);
	            break;

	        default:
	            // ignore this instruction
	            ;
	        }

	        if (*insns == kPackedSwitchSignature) {
	            width = 4 + insns[1] * 2;
	        } else if (*insns == kSparseSwitchSignature) {
	            width = 2 + insns[1] * 4;
	        } else if (*insns == kArrayDataSignature) {
	            u2 elemWidth = insns[1];
	            u4 len = insns[2] | (((u4)insns[3]) << 16);
	            width = 4 + (elemWidth * len + 1) / 2;
	        } else {
	            width = dexGetInstrWidth(gDvm.instrWidth, inst);
	        }
	        assert(width > 0);

	        insns += width;
	        insnsSize -= width;
	    }

	    assert(insnsSize == 0);
	    return true;
	```

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	}

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12. A computer-readable medium containing instructions for controlling a data processing system to perform a method for interpreting intermediate form object code comprised of instructions, certain of said instructions containing one or more symbolic references, said method comprising the steps of:	The Accused Instrumentalities include devices that store, distribute, or run Android or the Android SDK, including websites, servers, and mobile devices. They encompass a computer readable medium containing instructions for controlling a data processing system to perform a method for interpreting intermediate form object code comprised of instructions, certain of said instructions containing one or more symbolic references, to perform the steps described in the claim. *See* Claim 11, *supra*.
interpreting said instructions in accordance with a program execution control;	*See* Claim 11, *supra*. The Android platform has a Dalvik virtual machine that interprets intermediate form object code. Dexopt is part of the bytecode interpretation process because it’s a pre-pass made over the bytecodes to facilitate optimized bytecode execution. *See, e.g.*, dalvik\docs\dexopt.html; *see also*, http://android.git.kernel.org/?p=platform/dalvik.git;a=blob;f=docs/dexopt.html: …. **dexopt** We want to verify and optimize all of the classes in the DEX file. The easiest and safest way to do this is to load all of the classes into the VM and run through them. Anything that fails to load is simply not verified or optimized. Unfortunately, this can cause allocation of some resources that are difficult to release (e.g. loading of native shared libraries), so we don't want to do it in the same virtual machine that we're running applications in. The solution is to invoke a program called dexopt, which is really just a back door into the VM. It performs an abbreviated VM initialization, loads zero or more DEX files